GUIDELINES FOR THE GEOTECHNICAL INVESTIGATION AND ANALYSIS OF EXISTING EARTH DAMS

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Natural Resources and
Environmental Protection Cabinet
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KENTUCKY

PURPOSE

The purpose of this document is to outline the basic components of an adequate geotechnical investigation for dams and to provide a generalized set of guidelines for such an investigation. This booklet has been written pursuant to the provisions set forth in KRS 151.125(2).

An additional purpose of this document is to provide to dam owners a general outline of typical geotechnical investigations on earth dams. It has been the observation of this division that a general explanation and description of this type of investigation can be of benefit to dam owners by providing them with some background information on which to base their decisions. We further believe that engineers performing this type of work will benefit by having a better definition of the information we require in our analyses performed as part of construction permit application review and safety inspections.

The general application of this publication is limited to existing earthfill dams or other impounding structures constructed of earth or similar materials. Although some aspects may be applicable to any dam, care must be exercised in an extrapolation of this discussion.

REGULATORY REQUIREMENTS

Regulations which established minimum safety and design criteria for dams and associated structures were first promulgated in 1967. The regulation, 401 KAR 4:030, and Engineering Memorandum No. 5, which is a part of that regulation, applies to all dams and other potentially hazardous impounding structures. Any structure, including dams as defined in KRS 151.100, which might create a hazard to life or property is defined in Engineering Memorandum

No. 5 as having either moderate or high hazard potential. These classifications are repeated as follows:

1. CLASS (B) – MODERATE HAZARD. This classification may be applied for structures located such that failure may cause significant damage to property and project operation, but loss of human life is not envisioned. Such structures will generally be located in predominantly rural agricultural areas where failures may damage isolated homes, main highways or major railroads, or cause interruption of use or service of relatively important public utilities.

2. CLASS (C) – HIGH HAZARD. This classification must be applied for structures located such that failure may cause loss of life, or serious damage to homes, industrial or commercial buildings, important public utilities, main highways or major railroads. This classification must be used if failure would cause probable loss of human life.

The Division of Water is required by KRS 151.295 to perform safety inspections of all dams in Kentucky. These inspections are primarily visual but include such things as the review of plans and specifications, design data, and the performance of flood routings to determine the approximate rainfall which will overtop the dam. When inspections reveal conditions or deficiencies which may or do endanger life or property, KRS 151.297(1) requires that the owner be ordered to render the dam safe.

The process of rendering the dam safe requires that the owner's engineer evaluate the dam, determine the appropriate hazard classification, and design repair or reconstructive measures to bring the dam into compliance with the minimum safety criteria of the Commonwealth. If the dam is to remain in service, safety deficiencies must be corrected. Any structure which is to be modified or reconstructed must be made to conform to the criteria which have been established by the regulations.

Section 10 of regulation 401 KAR 4:030 requires that all structures, other than low hazard structures, have a complete subsurface investigation and soils

analysis submitted as an integral part of the drawings. The purpose of the investigation and analysis is to determine the stability of the structure and to assure that any repair or reconstruction results in the establishment of appropriate minimum factors of safety against slope failure.

BACKGROUND

Depending upon the source of reference, structural and seepage related deficiencies may account for 50 to 70 percent of dam failures. The evaluation of the geotechnical information is an essential component in the determination of structural stability. An adequate assessment of the safety of a dam must include a detailed geotechnical investigation and analysis. These determinations are generally made by civil engineers who are experienced in geotechnical engineering.

When applied to dams, geotechnical investigations should deal with such areas as exploration, instrumentation, seepage evaluation, soil sampling, soil testing and the performance of stability analyses.

For purposes of presentation, geotechnical investigations will be considered in three general phases:

1. Exploration
2. Testing
3. Analysis

It must be understood that these phases are highly interdependent. For example, a less than adequate subsurface exploration can greatly limit the useful information which would be obtained from the later phases of testing and analysis. There is no substitute for qualified, experienced personnel in the performance of each phase of this work.

Site conditions will have a great impact on the quantity of work that is necessary. Aspects such as the dam's height, length, function and importance may require that additional considerations be given to many aspects set forth in this document. Therefore, these guidelines can not, nor are they intended to be all-encompassing. However, these guidelines can be used by the owner as an indication of the minimum investigation which will be acceptable. It is felt that the engineer can justify, to the owner, other work which he determines will be necessary.

EXPLORATION

The term exploration as used in this phase of the geotechnical investigation refers to the subsurface work performed at the dam site. It includes such items as soil and rock borings and field testing and evaluations. Explorations are normally confined to the embankment and foundation materials at the dam unless there are explicit reasons for exploration in separated areas. Conditions which may call for additional investigation may includes such features as cavernous limestone foundations, landslide problems in the area, zones of faulting, and the investigation of potential borrow areas.

An area which should be examined in any exploration deals with available information. General geologic information is available from government agencies such as the United States Geological Survey (USGS) and the Kentucky Geological Survey (KYGS). Aerial geologic maps based on the 7 ½ minute topographic quadrangles are available for all of Kentucky and should always be reviewed as a part of any geotechnical investigation.

The exploration serves several functions which should include the specific items noted below:

1. Identification of soil horizons in the embankment and foundation, that is, soils with differing properties for engineering purposes.

2. Obtaining soil samples for subsequent laboratory testing.

3. Performance of field tests which can later be used to corroborate laboratory test results.

4. Determination of the level of the free water (phreatic) surface within the embankment.

5. Installation of instrumentation to monitor such things as slope movement and variations in the phreatic surface.

The number and location of borings which form the bulk of the exploration will vary, depending on the height and length of the dam, geologic conditions in the area and the complexity of the dam. The following list sets forth a minimum boring program which the division believes can establish a reasonable basis for subsequent analyses.

MINIMUM BORING LAYOUT

1. One (1) crest boring extending through the embankment and foundation materials to bedrock for each 250 feet of crest length, arranged such that one boring is located at or reasonably near the maximum section.

2. One (1) crest boring extending through the embankment and foundation materials to bedrock near each abutment; these borings should be located such that the phreatic line should be intercepted.

3. If access is reasonably attainable (side slopes not steeper than 3H to 1V or berms are present), one boring extending through the embankment and foundation materials to bedrock near each abutment near the mid height of the dam on the downstream slope of the dam; additional borings on the downstream slope should, if attainable, be taken at intervals not to exceed 250 feet.

4. One (1) boring opposite each boring advanced from the crest extending through the foundation material to bedrock along the toe of the dam.

Note: All borings should extend into the foundation material a minimum depth of one half the height of the embankment or to bedrock. Borings may be terminated in foundation soils when they penetrate a 'firm, impervious' stratum which will not settle, fail in shear or permit excessive seepage. This determination requires considerable judgment in certain cases and experience is very important.

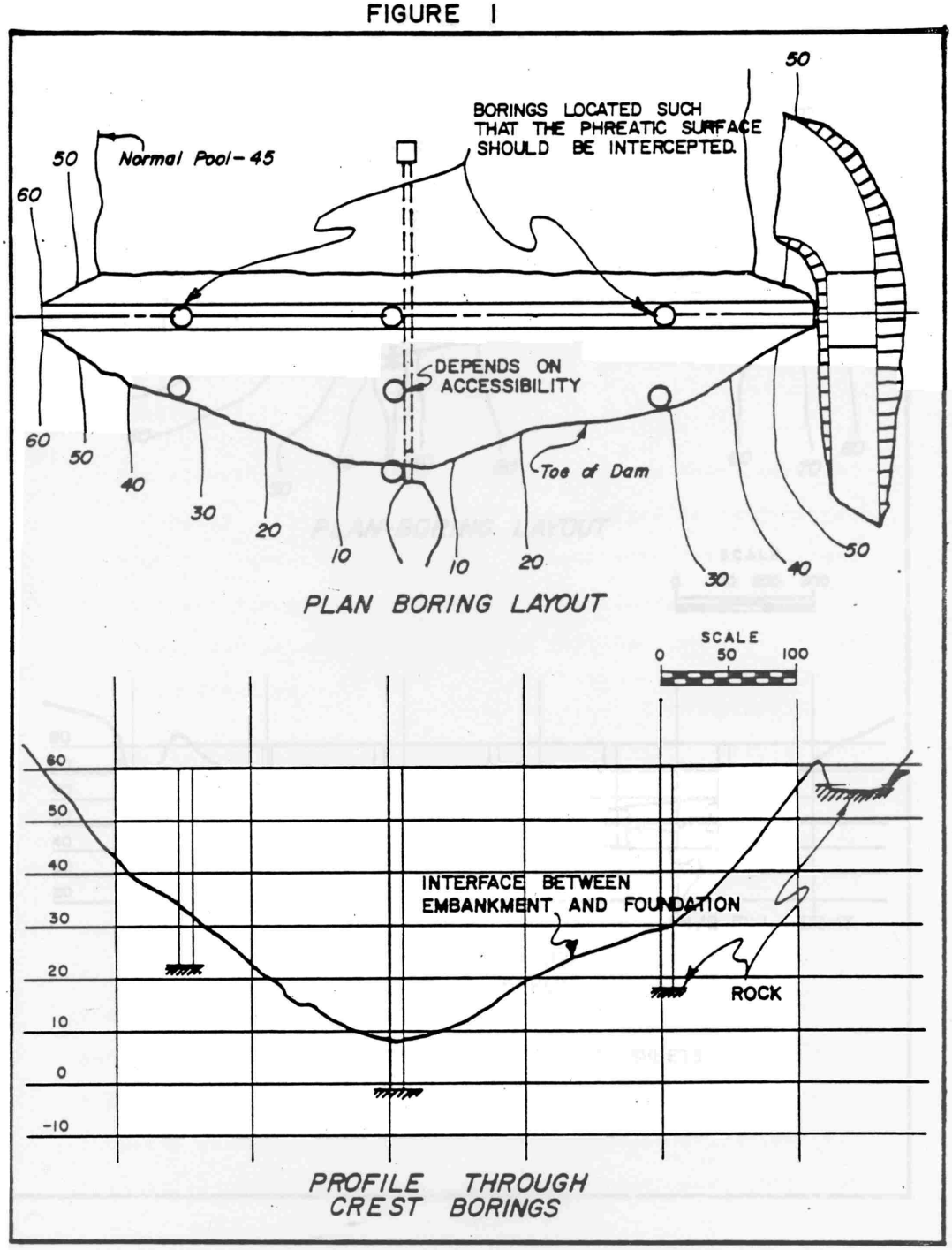
Note: Generally, to better establish the rock line, soil horizons and phreatic surface, borings on the crest, slope and at the toe should be located on or reasonably near cross-sections through the dam.

Borings may be desirable or necessary at other locations. Conditions which may require additional borings include seepage areas on or near the abutments, seepage areas along the toe of the embankment, data from previous investigations which show a lack of homogeneity of the embankment materials, and evidence that the embankment is zoned into distinctive areas of different materials.

For new construction, borings are usually required at the location of appurtenant structures such as spillway structures and open channel spillways. However, existing embankments usually do not require the geotechnical investigation of appurtenant structures unless there is evidence of instability, damage or the need for major modifications

All proposed borings should be approximately located in any engineering proposal submitted to this division. In the report on the actual investigation all borings must be accurately located on a boring plan and the elevation information noted on the boring log. The boring plan and logs should be plotted on scale drawings for ease of use. Examples of typical boring plans and logs are shown in Figures 1 and 2. These figures also provide an idea of typical layouts for borings on dams.

FIGURE 1


BORINGS LOCATED SUCH THAT THE PHREATIC SURFACE SHOULD BE INTERCEPTED.
Normal Pool-45
DEPENDS ON ACCESSIBILITY
Toe of Dam
PLAN BORING LAYOUT
SCALE
0 50 100
INTERFACE BETWEEN EMBANKMENT AND FOUNDATION
ROCK
PROFILE THROUGH CREST BORINGS